

- Hemiaster nobilis*, Dunc. & Sladen.
Hemiaster gibbosus, A. Agassiz.
Hemiaster zonatus, A. Agassiz.
Hemiaster Bowerbanki, Forbes.
Hemiaster Prestwichi, Forbes.
Hemiaster digonus, d'Archiac.
Hemiaster elongatus, Dunc. & Sladen.
Hemiaster carinatus, Dunc. & Sladen.
Hemiaster cavernosus, Phil.

We have purposely omitted the subgenera *Abatus* and *Tripylus*.

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XLIII.—*On some Remains of the Extinct Selachian Asteracanthus from the Oxford Clay of Peterborough, preserved in the Collection of Alfred N. Leeds, Esq., of Eyebury.* By A. SMITH WOODWARD, F.G.S., F.Z.S., of the British Museum (Natural History).

[Plate XII.]

SINCE the elaborate researches of Agassiz it has always been suspected that the dorsal fin-spines named *Asteracanthus* and the teeth named *Strophodus* originally pertained to one and the same fish; but no proof of the circumstance has been made known during the forty years that have elapsed since the publication of the 'Poissons fossiles,' and one of the commonest of Mesozoic fossils has thus remained undetermined among the miscellaneous group of "Ichthyodorulites." At last, however, it is satisfactory to be able to bring forward the requisite proof of this long-maintained surmise; and not only that, but also to make known some other important features in the anatomy of *Asteracanthus* which definitely decide its systematic position. Ample materials are furnished by the fine series of fossils from the Oxford Clay of Fletton, near Peterborough, in the collection of Alfred N. Leeds, Esq., of Eyebury; and I am indebted to the kindness of my friend for the pleasurable opportunity of studying these interesting specimens.

Five series of associated remains are of especial importance, and form the basis of the descriptions given below. They may be enumerated as follows, under Mr. Leeds's catalogue numbers :—

1. Two dorsal fin-spines, with two cephalic spines.
2. Two fragmentary dorsal fin-spines, with one fragmentary cephalic spine.
3. One dorsal fin-spine, with twenty teeth.
4. Two dorsal fin-spines, with numerous portions of cartilage and ninety-seven teeth.
5. Remains of the cartilages of the head, with eleven teeth.

Nos. 4 and 5 afford some slight information concerning the cartilages of the fish ; no. 1 makes known the singular cephalic spines ; while some differences between both the dorsal fin-spines and the teeth in nos. 3 and 4 render these also interesting from a systematist's point of view.

Cartilage.—The cartilages are only superficially calcified, though the film of fine granular material is thick compared with that of many living Selachians. Only one fragment (no. 5) seems worthy of description and illustration, namely the right mandibular ramus, which is shown from the outer aspect, of one third the natural size, in Pl. XII. fig. 1. This is much crushed and broken ; but it is interesting as showing the extremely robust character of the jaw. When complete the element must have had a length of about 0·27 m., being obtusely rounded in front, measuring about 0·085 in depth at the position occupied by the first series of lateral teeth, and gradually widening behind, until it attained a maximum depth of 0·14 at the condyle. On the inner side there is distinct evidence of a thickening of the cartilage of the lower margin immediately beneath the inferior limit of the tooth-bearing membrane ; and on the outer side a singular feature may be noticed, in the form of a protuberance slightly in advance of a point halfway between the condyle and the anterior extremity. Much of the external surface of the cartilage has a coarsely fibrous appearance, and at the point just mentioned several of these fibres curve upwards and backwards from the inferior margin in front, producing a large roughened boss (*t*), in which their abrupt upper extremities have the appearance of terminating. I have not been able to discover a similar protuberance in any other Selachian, living or extinct, and its exact meaning seems at present inexplicable. That it is a normal feature is proved by

its occurrence in both rami of two other mandibles in Mr. Leeds's collection; and the only explanation suggesting itself is that it relates to some attachment of ligaments or muscles specially adapted for the successful wielding of the unusually powerful dentition.

Dentition.—The teeth, most completely preserved in no. 4, are all detached, and those of both jaws mingled together in such a manner that the task of restoring the original dentition is somewhat difficult. Two or three definite facts, however, seem to form a satisfactory basis for a plausible attempt at a solution of the problem. In the first place, Sir Richard Owen has already determined the exact number and characters of the dental series in one jaw of the so-called *Strophodus medius**; and the homologous teeth can easily be recognized in the present collection. Secondly, in the jaw just mentioned there is no median symphyseal series, whereas among the Oxford Clay teeth there are five examples which must have undoubtedly occupied such a position; and it thus becomes probable that, as often in *Cestracion* †, one jaw had a median symphyseal row of teeth, while the opposing jaw possessed none. Thirdly, upon a fragment of the right mandibular ramus a few teeth of series 1 and 2 are actually preserved in position; so that these rows can be identified with complete certainty and by inference also their opposing series. And, lastly, placing the median row of teeth in the lower jaw the teeth of series 3 and 4 can readily be arranged to make the dentition of both jaws thus far of precisely the same extent. The intercalation of the median series and the greater relative length of the teeth of series 4 in the lower jaw precisely compensate for the greater relative length of the first three paired series in the upper jaw; and on this account I venture to think that the following determinations will prove for the most part well founded. Examples of the several teeth of the upper jaw are shown in Pl. XII. fig. 2, and a corresponding set from the lower jaw in fig. 3.

Commencing with the upper jaw, six teeth of series 1 are preserved upon the left side and seven upon the right. Each measures 0·025 m. in length and is much elevated, and the high arched crown is longitudinally keeled, narrowest anteriorly, and broadest at the point of its maximum elevation, nearer

* Geol. Mag. vol. vi. 1869, p. 194, pl. vii.

† Sir Richard Owen (Geol. Mag. vol. vi. 1869, p. 196) has remarked that in the lower jaw of *Cestracion* a median symphyseal row of teeth is present, while in the upper jaw it is absent. So far, however, as the present writer has had the opportunity of observing, the character is not constant.

the posterior than the anterior extremity. Of the teeth of series 2 five remain upon the left side and six upon the right. Each of these measures 0.037 in length and differs from a corresponding tooth of series 1 in its relatively less elevation and the almost complete absence of the longitudinal keel upon the crown. The teeth assigned to series 3 are very different from the foregoing; they measure 0.04 in length, and six of the left side and five of the right are available for study. The anterior extremity is still less truncated than the posterior; but the contour of the low crown is only gently sinuous, the posterior end being slightly upturned, and a more or less rounded elevation occurring somewhat in advance of the middle of the tooth. Series 4 is only preserved upon the left side, where it is represented by seven teeth, each measuring 0.048 in length, and differing from those of series 3 in the considerable forward flexure at the point of maximum coronal elevation. To series 5, 6, or 7, either of this or the opposing dentition, may also be referred two small elliptical teeth, of which one is shown in Pl. XII. fig. 4.

The five symmetrical median teeth assigned to the symphysis of the mandible have a much elevated, arched, longitudinally-keeled crown, and measure 0.023 in the longer transverse diameter. Those of series 1 only differ from the median teeth in their unsymmetrical character, being very similar to the corresponding opposing teeth; they measure 0.024 in length, and six of each side are preserved in addition to one incomplete germ on the right. The supposed teeth of series 2 are perplexing on account of their number, which at first sight leads to the suspicion of an error. No less than twelve teeth of each side can be identified, in addition to a germ on the right; and this number is equalled by no other known Cestraciont except *Cestracion*. Each tooth measures 0.029 in length and chiefly differs from a tooth of the opposing series 1 in its less elevation and the generally more truncated character of the posterior extremity. The teeth of series 3 much resemble those of series 2 of the upper jaw, but are relatively shorter, measuring only 0.034 in length; and of these four remain upon the left and six upon the right. The teeth assigned to series 4 are only preserved, to the number of five, upon the left; and their difference from those of the homologous upper series consists merely in their narrowness and great relative length, the latter measurement being at least 0.053.

Dorsal Fin-spines.—The two dorsal fin-spines associated with the dentition just described are shown, of two thirds the natural size, in Pl. XII. figs. 5, 6. They are nearly of equal

dimensions; but the posterior (fig. 6) can readily be distinguished by the evidence it bears of relatively deep and oblique insertion. Both spines are considerably crushed and abraded, and incomplete distally; but they appear to have been much compressed laterally, with a sharp anterior border. A very characteristic ornament is also preserved, consisting of small elongated tubercles, more or less arranged in series, and often fused above into delicate continuous ribs, which begin to prevail at a considerable distance from the upper extremity. The posterior face is slightly ridged, but the double series of denticles is almost destroyed. Measured from the extreme proximal limit of the ornament, the base of insertion of the first dorsal spine is almost precisely equal to that of the second; but the posterior opening of the central cavity is only 0.205 in length in the former, while in the latter it measures 0.235.

Cephalic Spines.—The cephalic spines of *Asteracanthus* are very similar to those of *Hybodus* and *Acrodus*, originally described by Agassiz under the name of *Sphenonchus**; but, as indicated by specimens nos. 1 and 2, these dermal weapons are relatively larger. One of them is shown, from the upper and lateral aspects, two thirds nat. size, in figs. 7 and 8. Two pairs of such spines occur upon the sides of the head of *Hybodus* and *Acrodus*; and the fossil now under discussion shows that there was also a paired arrangement in *Asteracanthus*. The base of insertion of the spine is very robust and somewhat saddle-shaped, but with one side-lobe much more developed than the other. The exerted portion is slender, gradually arched, rising backwards (or downwards) from the broader anterior (or upper) extremity, and terminating in a barbed point. At the base it is oval in section, being somewhat laterally compressed; and the only keels proceed, one from the point to the large inferior barb, thence diverging and disappearing, and the other from the point to the small lateral barb, from whence it is continued but also rapidly vanishes. The shining exposed surface is smooth, except superiorly upon the proximal half, where a few large longitudinal rugæ are to be observed.

Specific Determination.—On comparing the dorsal fin-spines described above with typical examples of *A. ornaticissimus* striking differences will at once be observed. If, indeed, these were isolated spines they might well receive a distinct specific name; and there are some peculiarities in the associated teeth which also might appear to justify the

* See E. Charlesworth, Mag. Nat. Hist. n. s. vol. iii. (1839), p. 245, with fig.; also E. C. H. Day, Geol. Mag. vol. ii. (1865), p. 565.

founding of a new species. Mr. Leeds's collection, however, comprises so large a series of dorsal spines from the Oxford Clay, and these exhibit so many variations in ornament—graduating from the type shown in figs. 5 and 6 to that of the most characteristic *A. ornatissimus*—that it seems quite impossible to discover any line of specific separation in the series. Indeed, the more the dorsal fin-spines of sharks are studied, the more impossible does it appear to employ variations in their surface-ornament for specific diagnosis; and it yet remains—at least in *Asteracanthus*—to determine what are the precise characters in the dentition to be counted as of real value. The teeth of series 3 and 4 in group no. 4 are relatively narrower and exhibit a more prominent coronal eminence than the corresponding teeth associated with the typical spine of *A. ornatissimus* in group no. 3. Fig. 9 represents a tooth, probably of series 3, of the latter, and fig. 10 two abnormal transversely-divided teeth, evidently of series 4 of the same fossil, and these agree more closely with the typical Kimmeridgian teeth from Shotover than those of the fish with finely ornamented fin-spines from Fletton. The general *facies* of the dentition, however, is identical in the two forms, and it thus seems most reasonable at present to describe the new one merely as a hitherto unrecognized variety under the name of *Asteracanthus ornatissimus*, var. *flettonensis*.

Conclusion.—From a study of the fossils just described it may be inferred, with much probability of correctness, that all the “species” of teeth named *Strophodus* are referable to the Selachian *Asteracanthus*. The spines and the teeth are often found together upon certain horizons; and the few cases in which they have not been thus discovered are worthless for consideration, being mere negative evidence. *Asteracanthus verrucosus*, for example, is common in the Purbeck Beds of Swanage, while not one tooth of “*Strophodus*” appears yet to have been discovered there; but spines of *Hybodus* are still more abundant in those beds, and it is scarcely minimizing to state that in all the public collections of Britain not more than a dozen teeth of this shark are to be seen from the same horizon.

The zoological result of this brief study is also interesting, demonstrating a still more close relationship between *Asteracanthus* and *Hybodus* and *Acrodus* than has hitherto been suspected. No vertebræ have been discovered with the remains of the Oxfordian genus, and it thus probably possessed a persistent notochord, like *Hybodus* and *Acrodus*. The dentition is fundamentally the same, only distinguished

by the reticulate ornamentation of the teeth and the absence of lateral cusps; the cephalic spines agree; and the dorsal fin-spines merely differ in the prevailing replacement of a ribbed ornament by series of stellate tubercles.

EXPLANATION OF PLATE XII.

Asteracanthus ornatissimus, var. *flettonensis*, A. S. Woodw., Oxford Clay, Fletton, near Peterborough.

- Fig.* 1. Right ramus of mandible, outer aspect, $\frac{1}{3}$ nat. size. *t*, tuberosity. [No. 5.]
Fig. 2. Teeth of upper jaw, series I-IV, upper aspect, nat. size. [No. 4.]
Fig. 3. Teeth of lower jaw, series 0-IV, upper aspect, nat. size. [No. 4.]
Fig. 4. Hinder tooth, upper aspect, nat. size. [No. 4.]
Fig. 5. Anterior dorsal fin-spine, lateral aspect, $\frac{2}{3}$ nat. size. [No. 4.]
Fig. 6. Posterior ditto, lateral aspect, $\frac{2}{3}$ nat. size. [No. 4.]
Fig. 7. Cephalic spine, lateral aspect, $\frac{2}{3}$ nat. size. [No. 1.]
Fig. 8. Ditto, upper aspect, $\frac{2}{3}$ nat. size. [No. 1.]
Fig. 9. Tooth of (?) series III, upper aspect, nat. size. [No. 3.]
Fig. 10. Two transversely-divided teeth of series IV, upper aspect, nat. size. [No. 3.]
Fig. 11. Hinder tooth, upper aspect, nat. size. [No. 3.]

(The numbers refer to the Catalogue of the Leeds Collection.)

XLIV.—*Description of a Large Variety of Orbitolites Mantelli, Cart., from the West Bank of the River Irrawadi, in the Province of Pegu, Burma, about 36 miles above Prome.*
 By H. J. CARTER, F.R.S. &c.

Orbitolites Mantelli, var. *Theobaldi*, n. var.

Discoid, slightly undulous, flat, thin. Consisting of a well-marked central plane of ?-spheroidal cells in juxtaposition, bordered on each side by several layers of vertically compressed ones presenting a more or less columnar arrangement. Central plane thinnest in the centre (where it generally commences around one or more comparatively large "primary cells" in conjunction, by which the centre, when thus exposed, is easily ascertained), increasing slightly in vertical diameter towards the circumference; structure of the central plane, when viewed in a vertical section, passing through the "primary cells" or centre of the fossil, presenting, for the most part, quadrangular spaces. Disk of the largest specimen exposed about $3\frac{1}{8}$ inches in horizontal diameter by $\frac{1}{8}$ inch